Effect of Dryland Leveling on Soil Moisture Storage and Grain Sorghum Yield

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DEFICIENT moisture on nonirrigated land has caused researchers and others to seek ways to use precipitation more efficiently. One approach has been through land leveling to retain and uniformly distribute intense precipitation which would otherwise run off or collect in depressions*.

Much of the dryland leveling in the United States has been concentrated in the Lower Rio Grande Valley of Texas where approximately 15,000 acres have been leveled during recent years. Although the benefits from this practice may appear obvious, certain essentials for success have been discussed by Robins†. They are: (a) runoff must be appreciable and somewhat regular in occurrence, (b) runoff must occur when additional moisture can be stored and effectively used by crops, (c) soil moisture storage capacities must be high, and (d) suitable crops that can use the additional water must be grown. Field measurements of the ways in which various areas meet these essentials are limited. Hatchett and Marion (3)‡ at Spur, Texas, obtained increased cotton yields from benching 0.5 to 1 percent slopes during a two-yr period. However, Hauser and Cox (4) noted little or no benefit from bench leveling alone at Bushland, Texas.

The study reported in this paper was initiated to determine the effect of leveling dryland areas on moisture storage and grain sorghum yield in the Lower Rio Grande Valley of Texas.

EXPERIMENTAL PROCEDURE AND SITE DESCRIPTIONS

The study was conducted on three paired sites (six fields), one leveled and the other not leveled, at three locations in the Lower Rio Grande Valley§. Sites 1 and 2 were in Willacy County and site 3 in Cameron County, Texas. Data were collected from sites 1 and 2 in 1961 through 1963 and from site 3 in 1962 through 1964.

An 8-row transect (strip) was established across each level and adjacent nonleveled field. All soil, moisture, and crop measurements were made within this 8-row transect.

Soil moisture was measured with a neutron meter before seeding, twice during the growing season, and after harvest each year at depths of 6 in. and 1, 2, 3, 4, 5, and 6 ft. Moisture-sampling sites were located at obvious topographic changes across the nonleveled fields and at various "cut" and "fill" locations across the leveled fields.

Water-table elevations were determined in piezometers installed at the ends of each field, and rainfall was measured with a standard U.S. Weather Bureau rain gage located on each site.

Hybrid grain sorghum was seeded annually as the test crop in the 8-row transects, and grain yields were delineated at topographic changes on the nonleveled and at "cut" and "fill" areas on the leveled fields. Previous cropping involved a cotton and grain sorghum rotation.

Possible variation in nitrogen status between fields and along the transects was reduced by applying 125 lb of ammonium nitrate (33.5 percent N) per acre each yr before seeding.

There were no marked differences in soil texture, soil density, available soil moisture, and available phosphorus between the leveled and nonleveled fields at the same site. Sites 1 and 3 are classified as Willacy sandy clay loam and site 2 as Delfina fine sandy loam.

Soil salinity affected site 1 in varying deg along the transects. All areas exhibiting visual plant symptoms of soil salinity were not harvested and hence are not included in the yield data. Site 2 was saline below 3 ft ($\geq$ 4 mmho per cm) but did not exhibit visual plant symptoms of soil salinity. The lower root zone salt may have uniformly reduced crop yields (5), however. Site 3 was nonsaline ($\leq$ 1 mmho per cm) within the 6-ft profile sampled.

All leveled fields were designed for zero graded (flat) in all directions. However, surface elevations along the 8-row transects revealed several deviations from the design grade. The maximum difference in elevation across the leveled fields was 0.35, 0.35, and 0.8 ft at sites 1, 2, and 3, respectively. Nonleveled field profiles along the transects revealed a somewhat "hummocky" or undulating surface topography in some portion of the field. Site 2 has a depression near the transect center that collects runoff. Very little runoff water leaves the field area of site 1; however, water moves from high to low areas within the field. Runoff water leaves the site 3 nonleveled field via an open, surface drainage ditch.

RESULTS AND DISCUSSION

Rainfall and Water Table Observations

Test-period rainfall is given in Table 1. Annual rainfall was near normal in 1960, 1961 and 1963, whereas in 1962 it was considerably below normal, especially at sites 1 and 3. Omitting June rains, which are usually too late to benefit spring-seeded grain sorghum in the Lower Rio Grande Valley, crop season rainfall (February to May) varied between 34 and 70 percent of normal. Preseason rainfall varied between a minimum of 8.82 in. (53 percent of normal) on site 3 in 1962-63 and a maximum of 21.8 in. (130 percent of normal) on site 1 in 1960-61.

A high regional water table that fluctuates in response to local rainfall underlies the nonirrigated coastal plain of the Lower Rio Grande Valley||. The water table elevation at seeding and harvest was as follows:

Site	1961 Seeding,	harvest	1962 Seeding,	harvest	1963 Seeding,	harvest	1964 Seeding,	harvest
	Ft below surface							
1	2.0	4.9	3.1	4.6	6.4	4.4	....	....
2	10.8	10.7	11.3	11.4	11.9	11.3	....	....
3	....	....	9.8	12.1	13.5	13.4	13.7	13.8

The high water table undoubtedly influenced moisture storage, moisture use, and crop yield at site 1.

Soil Moisture

Fallow-period moisture loss (rainfall plus 6-ft profile change) varied among

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* Ross, P. Earl, and Ussery, L. Roy, ASAE paper No. 60-713 (Land Leveling for Dryland Agriculture).

† Robins, J. S., July 28-30, 1960, "Terrace Benching and Land Leveling to Conserve Moisture" (Proceedings of the Great Plains Agricultural Council meeting).

‡ Numbers in parentheses refer to the appended references.

§ The author is indebted to Messrs. Billy Darling, Ervin Pfau, and George Labar who provided land at sites 1, 2, and 3, respectively.

|| Allen, R. R., Ussery, L. R., and Taylor, B. M., 1964, "Ground Water Table and Salinity Conditions in the Nonirrigated Area of the Lower Rio Grande Valley of Texas." (Unpublished manuscript)

TABLE 1. MONTHLY RAINFALL DURING THE CROP SEASON, ANNUAL RAINFALL, AND QUANTITY RECEIVED BETWEEN CROP SEASONS (1961-64)

Year and site	Annual	February	March	April	May	June	Total crop season	Between crop season, July-January
	Inches							
1931-60*	26.53	1.15	1.30	1.45	3.48	2.46	9.84	16.69
1960								
Site 1	26.73							21.85
Site 2	25.43							21.73
1961								
Site 1	24.89	0.07	0	2.02	0.47	2.71	5.27	18.90
Site 2	25.09	0.07	0	2.37	0.11	4.91	7.46	16.81
1962								
Site 1	16.71	0	1.20	0.57	0.66	3.03	5.46	11.42
Site 2	20.68	0	1.65	0.66	0.72	5.23	8.26	12.18
Site 3	15.36	0	1.22	0.62	1.26	2.91	6.01	8.82
1963								
Site 1	27.25	0.33	0	0	3.57	7.64	11.54	....
Site 2	....	0.41	0	0	2.11	7.41	9.93	....
Site 3	24.26	0.41	0	0.95	3.78	5.03	10.17	14.35
1964								
Site 3	....	1.32	0.03	0.45	1.97	4.19	7.96	

* Raymondville, Texas

years and sites but averaged about 13 in. for the study period (Table 2). Consequently preseason rainfall storage averaged 6 percent in the 6-ft soil profile at seeding. Individual site losses by years were directly related to fallow rainfall quantity; *i.e.*, larger rainfall amounts resulted in larger moisture losses during the period. No fallow moisture-loss differences were noted between leveled and non-leveled fields at sites 1 and 2. The leveled field of site 3 lost 2.94 in. more moisture than the nonleveled field during the 1963-1964 fallow period.

Only four dates were available to determine the immediate leveling effects on stored moisture following runoff-producing rains. These dates and the average stored moisture differences between leveled and nonleveled fields per 6-ft profile were:

Site	Date	Stored moisture difference (in.)
2	1961 (after harvest)	Leveled 1.07 < nonleveled
3	1962 (after harvest)	Leveled 0.93 > nonleveled
1	1963 (after harvest)	Leveled 2.64 > nonleveled
3	1963 (after harvest)	Leveled 3.18 > nonleveled

Measuring dates varied between 3 and 8 days after the rainfall events.

There were no marked profile moisture differences at seeding between leveled and nonleveled fields (Table 3). The leveled field profiles contained slightly more stored moisture in 1962 at sites 2 and 3, and at site 3 in 1963. The measured moisture use (evapotranspiration) during the crop season was low compared with other published Southern Plains data (1, 2). The low measured moisture use at site 1 can be explained by the high, fluctuating water table that exists at the site. However, it seems unlikely that a water table of 11 and 13 ft at sites 2 and 3 would furnish appreciable quantities of water to the sorghum plants.

On the average, the leveled field of sites 1 and 2 indicated a more uniform moisture distribution across them at seeding than the adjacent nonleveled fields. The stored moisture variation across the leveled fields is related to leveling job quality (miscrorelief variations) and to soil texture (water-holding capacities). Site 3 exhibited more within-field variation in stored moisture at seeding for the leveled field than the nonleveled field, due to a poor leveling job and to higher clay content at one sampling location.

Crop Yields and Moisture-Use Efficiency

Grain sorghum yields on a field basis and moisture-use efficiency are presented in Table 4. Approximately 400 lb per acre yield differences were noted in favor of the leveled fields at sites 1 and 3 in 1963. Other yield differences were too small to be significant in practical farming operations. Average test-period yields show only slight differences of 50, 50, and 80 lb per acre in favor of the leveled fields of site 1, 2, and 3, respectively.

The leveled-field yield results generally agree with those of Hauser (4) who noted little or no benefits from bench leveling alone (no watershed at Bushland, Texas, during 1958-60). There were no consistent yield differences between cut-and-fill areas across the level fields.

Moisture-use efficiency varied between yrs at the same site. Average moisture-use efficiencies for sites 1 and 3 were high compared with expected nonirrigated values of 200 lb per acre-in. of water or less (6). The high measured moisture-use efficiency indicated at site 1 suggests substantial water use from the water table (5). However, site 3 in 1964 (13-ft-deep water table) indicates that grain sorghum makes efficient use of water, provided high profile moisture exists at seeding.

Interpretations

In order to explain the response or lack of response from leveling nonirrigated land in the Lower Rio Grande Valley, several factors that could affect soil moisture and cause differences between leveled and nonleveled fields need to be evaluated. These factors may be classified broadly as climatic effects, topographic effects, and soil effects.

The principal climatic effects are frequency and timeliness of runoff-producing rains and the annual rainfall distribution. Factors that tend to eliminate stored moisture differences between leveled and nonleveled fields are water-table depth, evapotranspiration, and monthly rainfall distribution. The normal monthly rainfall amounts for the Lower Rio Grande Valley indicate two periods when runoff-producing rains are likely to occur. These periods are May to June and August to October, with May and September the peak rainfall months. It should be noted that monthly rainfall varied greatly from the mean for individual years, es-

TABLE 2. MOISTURE LOSS (RAINFALL PLUS 6-FT PROFILE CHANGE) DURING FALLOW PERIOD (HARVEST TO SEEDING) AT EACH TEST SITE

Site	H 1961 to S 1962 Level	H 1961 to S 1962 Nonlevel	H 1962 to S 1963 Level	H 1962 to S 1963 Nonlevel	H 1963 to S 1964 Level	H 1963 to S 1964 Nonlevel	Average Level	Average Nonlevel
	Inches							
1	15.11	15.15	13.29	13.57	....	....	14.20	14.36
2	13.61	13.53	12.43	12.56	....	....	13.02	13.04
3	....	....	7.57	8.34	16.37	13.43	11.97	10.88
Ave.	14.36	14.34	11.10	11.49	16.37	13.43	13.06	12.76
30-yr normal rainfall							16.69	

TABLE 3. TOTAL STORED MOISTURE AT SEEDING AND MEASURED CROP SEASON MOISTURE USE AT EACH TEST SITE

Treatment	Moisture storage at seeding 1961	1962	1963	1964	Moisture use during crop season 1961	1962	1963	1964
	In. per 6-ft profile				In.*			
				Site 1				
Level	26.88	25.35	22.50	....	10.81	6.77	6.11	....
Nonlevel	26.30	25.00	22.17	....	10.50	6.48	8.40	....
				Site 2				
Level	20.63	20.42	21.85	....	10.72	6.99	10.49	....
Nonlevel	20.82	19.52	21.88	....	9.84	6.00	10.14	....
				Site 3				
Level	....	21.20	17.76	21.26	....	10.11	6.40	7.21
Nonlevel	....	20.42	16.91	21.02	....	10.26	7.89	7.18

* Depletion in 6-ft profile plus rainfall.

TABLE 4. HYBRID GRAIN SORGHUM YIELD AND MOISTURE USE EFFICIENCY FOR LEVELED AND NONLEVELED FIELDS

Site	1961 Level	1961 Nonlevel	1962 Level	1962 Nonlevel	1963 Level	1963 Nonlevel	1964 Level	1964 Nonlevel	Average Level	Average Nonlevel
	Grain yield, lb per acre									
1	4,020	4,120	3,790	3,910	3,450	3,060	....	....	3,750	3,700
2	2,750	*	2,220	2,020	2,550	2,650	....	....	2,380	2,330
3	....	....	5,020	5,130	1,730	1,330	2,860	2,900	3,200	3,120
	Moisture use efficiency, lbs of grain per in. measured moisture used†									
1	372	392	560	603	565	364	....	....	499	453
2	257	*	318	337	243	261	....	....	280	299
3	....	....	497	500	270	169	397	404	388	358

* Combined by mistake.
† Depletion in 6-ft profile plus rainfall.

pecially during the summer months. June rainfall is usually too late to benefit spring-seeded grain sorghum. September and October rainfall occurs during the fallow period. Therefore, May is the only month in which runoff-producing rains may be expected that would benefit growing grain sorghum on leveled fields. No runoff-producing rains occurred in May at any site during the test period. The peak rainfall month of September has the highest probability for the occurrence of runoff-producing rains that could cause differences in stored moisture between leveled and nonleveled fields. These differences must persist through the fallow period to benefit the succeeding crop.

High water tables (in some cases), low monthly rainfall during the four months before seeding, fairly high fall and winter temperatures, and perhaps percolation below 6 ft (possible at site 2 and 3) apparently equalized soil-profile moisture storage that occurred following heavy rains.

At site 1 in 1961, rains totaling 8.55 in. fell in September. The water table rose within 6 in. of the soil surface, then receded to 3.1 ft by seeding time 1962. Only 1.50 in. of additional rain fell from October 1961 through February 1962, and soil profile moisture per 6 ft was essentially equal for the leveled and nonleveled field at seeding (Table 3).

In 1963 the leveled field (site 1) contained 2.64 in. more stored moisture in the 6-ft profile after harvest. However, additional rainfall, water-table effects, and evapotranspiration had equalized soil moisture between fields by seeding in 1964.

Site 3 in 1963 illustrates the combined equalizing effects of additional rainfall, evapotranspiration, and percolation on stored soil moisture during the fallow period. The leveled field contained 3.18 inches more moisture per 6 ft after harvest than the nonleveled field. Four months later, after 9.22 in. of cumulative rainfall (no runoff-producing rains), profile moisture contents were equal. The leveled field had lost 2.37 in. and the nonleveled field had gained 0.64 in. per 6 ft of profile. The water table had remained nearly constant at 13 ft.

Topographic features also influence the quantity of soil moisture stored. Microrelief variations across leveled fields affect moisture distribution. Topographic features of nonleveled fields may or may not permit runoff from the field or the local area. Because of a "hummocky" or undulating microrelief, water that runs off elevated portions of a field commonly collects in depressions adjacent to or surrounding the elevated portions. Thus average soil-moisture contents on a field basis may remain equal between leveled and nonleveled fields.

Several factors appear to affect crop yield on both leveled and nonleveled fields. These include timeliness of crop-season rainfall, profile moisture at seeding, soil salinity, and water-table depth and fluctuation.

A striking example of the importance of timely rainfall during critical grain-sorghum growth stages is revealed in the following data from site 3 in 1962 and 1964:

Year	Profile moisture at seeding	Rainfall during growth periods: Seeding to boot	Boot to soft dough	Soft dough plus 3 wks	Total	Grain yield
	In. per 6 ft	Inches				Lb/A
1962	20.81	1.62	1.33	0.57	3.52	5,072
1964	21.14	0.48	0.20	1.77	2.45	2,876
1963	17.33	0	4.73	0	4.73	1,530

A comparison of the moisture and yield data for the years 1963 and 1964 illustrates the importance of soil-profile moisture at seeding.

Although this report places major emphasis on moisture storage and crop yield, it should be noted that precise, nonirrigated land leveling has other advantages. It reduces the need for surface drainage, permits plowing and cultivation of all the field at one time, and provides a uniform surface for the operation of farm machinery.

Summary

The effects of leveling nonirrigated land on stored soil moisture and hybrid grain-sorghum yield were studied for three yrs at three paired sites (one leveled, the other nonleveled) in the Lower Rio Grande Valley of Texas. Evaluation of these effects was complicated by rainfall distribution and variability, flat-to-undulating surface topography, high regional water tables, high evapotranspiration, and soil salinity in the upper and/or lower root zone.

Although leveled fields showed more stored moisture than non-leveled fields (with one exception) following fallow-season, runoff-producing rains, these differences largely disappeared by seeding time. Only about 6 percent of fallow-season rainfall was stored in the 6-ft soil profile at seeding.

Average test-period grain yields showed slight advantages of 50, 50, and 80 lb per acre in favor of the leveled fields of sites 1, 2, and 3, respectively. In the absence of a high water table, grain yields depended on profile moisture at seeding and on timeliness of rainfall during critical growth stages.

Other possible advantages of nonirrigated land leveling are noted.

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